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Chapter

Characteristic on the Stability of *Haloxylon Ammodendron* Plantation in the Southern Fringe of Gurbantunggut Desert, Northwest China

Qinghong Luo, Qimin Chen, Miao He and Na Li

Abstract

Using chronosequence theory and method, the characteristics of vegetation-soil coupling and structure stability of *Haloxylon ammodendron* plantations in the southern fringe of Gurbantunggut Desert were analyzed. The results showed, the canopy storey of *H. ammodendron* plantation experienced three stages, rapid growth (the age of 7 to 20), then slow growth (the age of 20 to 28) and last decline (over the age of 28). The best natural regeneration started from 17-yr-old plantation. Vegetation-soil system coupling degree (C) and coupling coordinative degree (D) of plantations with different age were not one-to-one correspondence. The system of *H. ammodendron* plantations always stayed in disorder recession, vegetation and soil were prone to loss type during the process of sand-fixation. Five principal components evaluated that the first rank was 42-yr-old plantation. It was inferred that the trend of the vegetation and soil system was from senescence to harmonious development. So the trend of coordinated development between vegetation and soil would be promoted, if the artificial tending and management measures strengthened.

Keywords: *Haloxylon ammodendron* plantation, structure dynamic, survive and death curve, vegetation-soil coupling degree, coupling coordinative degree

1. Introduction

Structure and function are two vital aspects to determine and measure the stability of forests community [1]. Population structure, which reflects the distribution of individuals within a population, may provide insights into past and present regeneration [2, 3]. Life table and survival curve are the main methods when analyzing population structure. By using life table analysis, it was discovered that *H. ammodendron* seedling had two rapid drop stages of survival rate and high mortality rate in natural forest [4]. Meanwhile, by using survival curve analysis, *H. ammodendron* population was suggested closing to progressive or stable status in some suitable habitats [5, 6]. This, however, has been unknown in the plantation which had similar inhabits but different growth stage.

Plantation has been applied in ecological restoration worldwide [7]. A key issue for plantation is that population regeneration is often challenged by seedling

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establishment in many plantation ecosystems, which is critical to the stability of plantation species as well as to the plantation sustainability [8]. For *H. ammodendron*, failure in regeneration resulted in the population degradation occurred in old stand in the Hexi Corridor Desert [9, 10], suggesting that the regeneration barrier possibly occurs in *H. ammodendron* plantation. This, however, has not been assessed in the biggest *H. ammodendron* plantation developed in the Gurbantunggut Desert edges.

The wind prevention and sand fixation forest ecosystem, which is a kind of relatively heterogeneous open system, and flow of the material, energy and information constantly happens among the subsystems, thereinto, the two major subsystems, vegetation and soil formed an interdependent and mutually restrictive relationship between them [11]. Exploring the relationship between vegetation and soil has significant meaning in understanding the process and effect of sand fixation vegetation, and further putting forward corresponding optimal management measures [12]. In the ecological process of settlement, growth and succession of artificial *H. ammodendron* population, the accumulation and distribution of soil moisture and nutrient will change. In turn, that will affect the characteristics of vegetation. Therefore, such mutual restriction relationship between vegetation and soil will definitely change according to the spatial and temporal scale [13].

The Gurbantunggut Desert in northwestern China, the third largest desert in the world, is sensitive to climate change and human activities [14]. The desert vegetation is dominated by the *H. ammodendron*, which is greatly tolerant to drought, wind erosion, sand burial and other stress factors [15–18]. Therefore, *H. ammodendron* has been widely used in vegetation restoration and sand-fixation engineering [19]. In the edge of the Gurbantunggut Desert, i.e., the desert-oasis ecotone, *H. ammodendron* forest play an important role in preventing dune movement toward oasis. However, large area of *H. ammodendron* forest was suffered deforestation and overgrazing during the 1970s and 1980s, which leads to severe desertification in this area [20]. Since then *H. ammodendron* plantation has been extensively developed along the edge of the Gurbantunggut Desert. In recent decades, these *ammodendron* plantations have gradually developed into the mature stage, but, some of them tend to decline, which directly threatened the stability of the artificial population system and the normal exertion of ecological functions in this area.

This chapter, the change characteristics of the canopy storey and the regeneration storey structures of *H. ammodendron* plantations at different chronosequence stages, as well as the growth and death dynamic development law of populations ware studied. Meanwhile, the feedback relationship between vegetation and soil were analyzed. Further, the current situation of growth and development of *H. ammodendron* population in the edge of the Gurbantunggut Desert was evaluated accurately and comprehensively. Then, we explained why the *H. ammodendron* population is stable, developing or declining, and whether *H. ammodendron* plantation has the ability of sustainable natural regeneration. On this basis, we put forward the scientific suggestion for the vegetation construction and management of the degraded artificial forest ecosystem in this region. We hope this research could provide basic data and scientific evidence for further research on the vegetation restoration and reconstruction of desert ecosystem in arid region.

2. Characteristics of vegetation and soil system of *H. ammodendron* plantation

2.1 Basal characteristic of *H. ammodendron* plantations in study site

In Mosuowan Reclamation Area, Corps 150, southern edge of the Gurbantunggut Desert, *H. ammodendron* plantations were chosen for this study, which are constructed on moving sandy land within an area of about 57.61 km^2. Thus soil and climate is similar among these plantations. All plantations were established by transplanting 1-yr-old *H. ammodendron* seedlings in regular spacing (**Table 1**). Thus *H. ammodendron* individuals could be classified into two main storeys, i.e. transplanted individuals (canopy storey) and seedlings including those naturally regenerated between transplanted ones (regeneration storey). None of the plantations were subjected to irrigation, pruning, thinning or any other silvicultural practices after transplantation. In addition, no incident of insect, rodents and fire was recorded since 1981. Except *H. ammodendron* seedlings, understory plants were dominated by *Ceratocarpus arenarius* and *Salsola ruthenica*, with a low total cover less than 8%. (**Table 1**, **Figure 1**).

In August, when soil water content of the study site was relatively stable and close to the average level in a year [21], vegetation survey was carried out in nine *H. ammodendron* plantations. In each plantation, three 20 m × 30 m sample plots were established, with each at least 100 m away from the others. Within each sample plots, the numbers of survived and dead individuals for canopy storey was recorded (**Table 1**). Meanwhile, height, basal stem diameter and crown width (north–south and east–west) of survived individuals were measured one by one. Then the crown projected area, above-ground biomass and canopy density of major storey were calculated according to Phillips and Macmahon's ellipse formula [22] and Song's Eq. [23], respectively.

2.2 Characteristics of canopy storey in six *H. ammodendron* plantations at different Chronosequence stage

Vegetation survey was carried out in six *H. ammodendron* plantations, which having capacity of normal natural regeneration. According to Rundel's method [24], combining with the characteristic of slow growth and false ring of H. ammodendron [25], the structure of canopy storey was analyzed by quantity and size dynamic of tree height and basal stem diameter. Tree height class was divided into 0 ~ 0.5 m, 0.5 ~ 1.0 m, 1.0 ~ 1.5 m, 1.5 ~ 2.0 m, 2.0 ~ 2.5 m, 2.5 ~ 3.0 m, 3.0 ~ 3.5 m, 3.5 ~ 4.0 m, 4.0 ~ 4.5 m, 4.5 ~ 5.0 m, 5.0 ~ 5.5 m and 5.5 ~ 6.0 m. Basal stem diameter was divided into 0 ~ 1 cm, 1 ~ 2 cm, 2 ~ 4 cm, 4 ~ 6 cm, 6 ~ 8 cm, 8 ~ 10 cm, 10 ~ 12 cm, 12 ~ 14 cm, 14 ~ 16 cm, 16 ~ 18 cm and 18 ~ 22 cm. Structural characteristics of main layer were analyzed by quantity and size.

As shown in **Figures 2** and **3**, in the growth process of *H. ammodendron*, the distribution centers of height class and basal stem diameter class of the canopy storey

Chronosequence Stage (yr)	Location (N, E)	Altitude (m)	Planting space (m)	Preserving rate (%)
7	45°05′4.4″, 85°59′26.9″	330	1.5 × 2	99.3
12	45°01′56.8″, 86°08′22.2″	332	2 × 3	98.2
15	44°39′35.4″, 86°20′12.4″	344	2 × 2	91.4
17	45°08′5.4″, 85°59′26.0″	319	1 × 5	100
20	45°02′48.8″, 86°08′48.7″	328	3 × 3	97.2
23	44°34′29.1″, 83°18′49.4″	310	2 × 2	81.9
28	45°07′48.8″, 85°58′35.0″	314	3 × 4	95.4
33	45°10′33.5″, 85°55′35.1″	309	1 × 5	93.4
42	44°01′56.8″, 86°08′22.3″	320	1 × 5	91.7

Table 1.
The sample plots information of H. ammodendron *plantations at different chronosequence stage.*

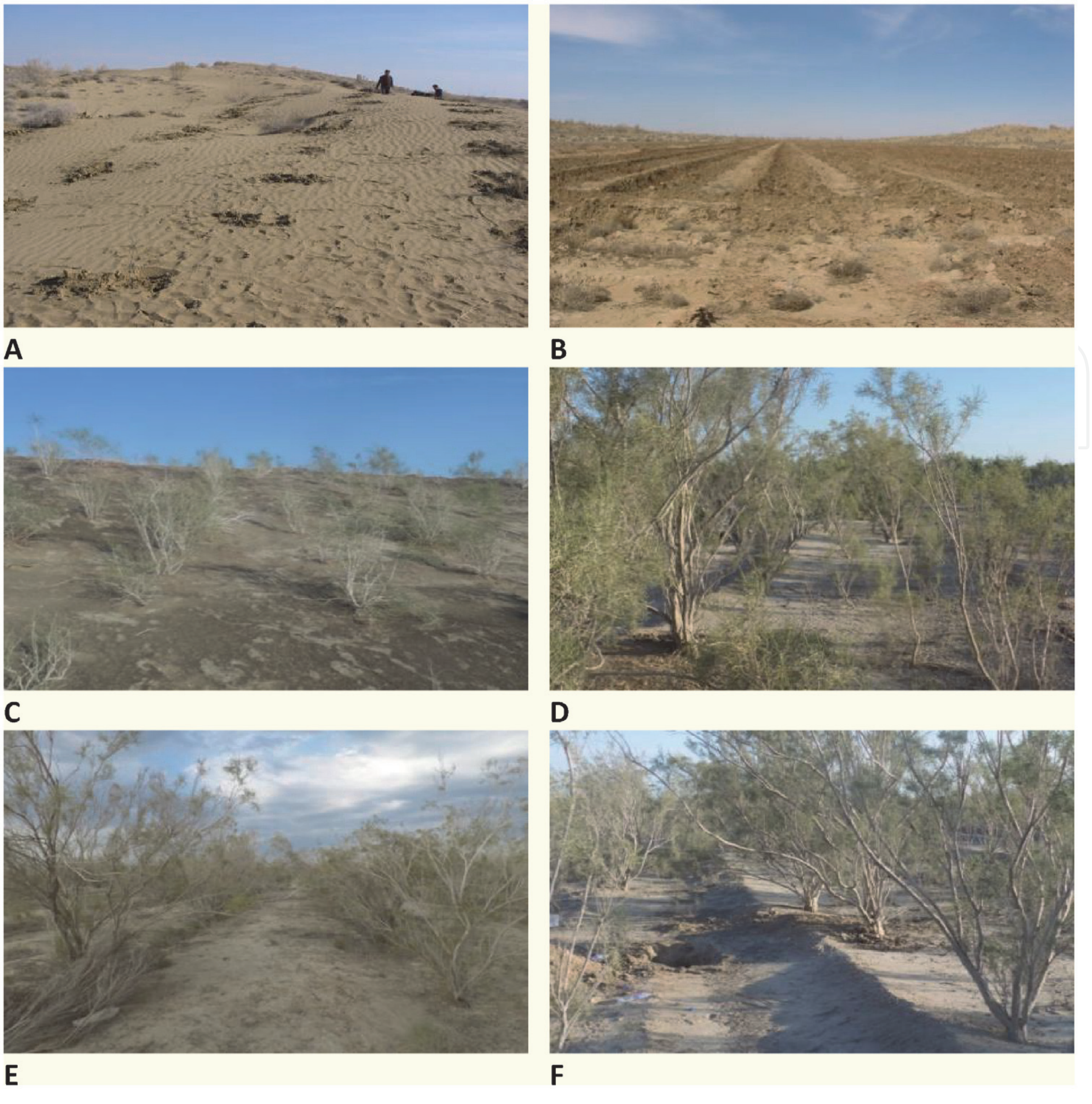

Figure 1.
The original appearance (A), land preparation (B), the H. ammodendron *plantation with age of 7 (C), 17 (D), 28 (E), 42 (F).*

moved to a higher section gradually, and the structure of size class showed a trend of continuous differentiation first and then concentration. It indicated that the intra-specific competition among individuals was intensifying, and the population structure tended to be more and more complex, which was conducive to the rational use of spatial resources. The tree height and basal stem diameter class of canopy storey showed obvious differentiation in the plantations with the age of 17 and 20. It indicated that, after the competition and self-thinning, some individuals having competitive advantage had entered in the rapid growth stage, and most individuals could grow to the canopy storey (HT 2.5–3.0 m, BSD 8-10 cm). After the age of 28, *H. ammodendron* plantation would start to decline, when branch aging and withering appeared, and the natural death rate of *H. ammodendron* in canopy storey would reach 5% ∼ 8%.

2.3 Characteristics of regeneration layer in six *H. ammodendron* populations at different chronosequence stage

2.3.1 Characteristics of seedling with different grade

Following the method of the Blackman [26] and Forest resources planning survey [27], seedlings in regeneration storey were divided into three grades, namely grade I

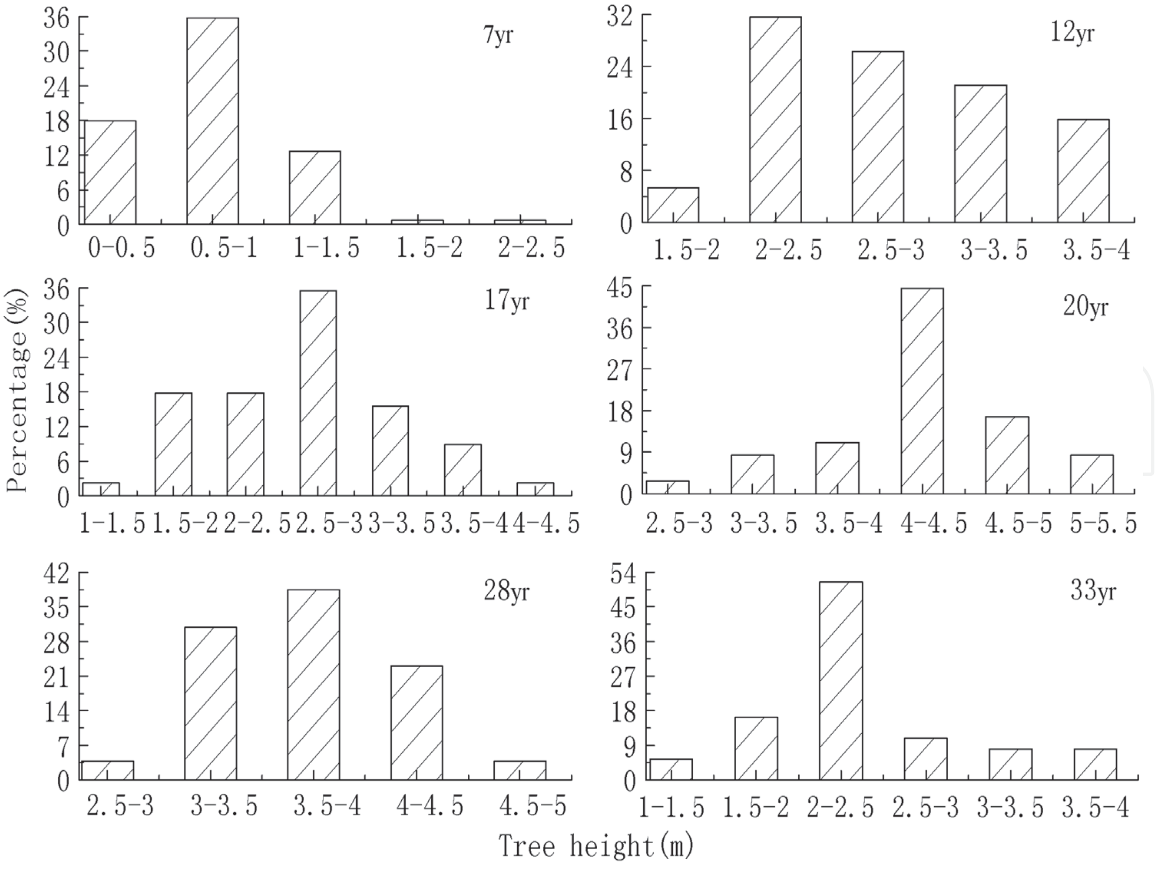

Figure 2.
Dynamitic distribution of H. ammodendron *height (HT) in canopy storey at different chronosequence stage.*

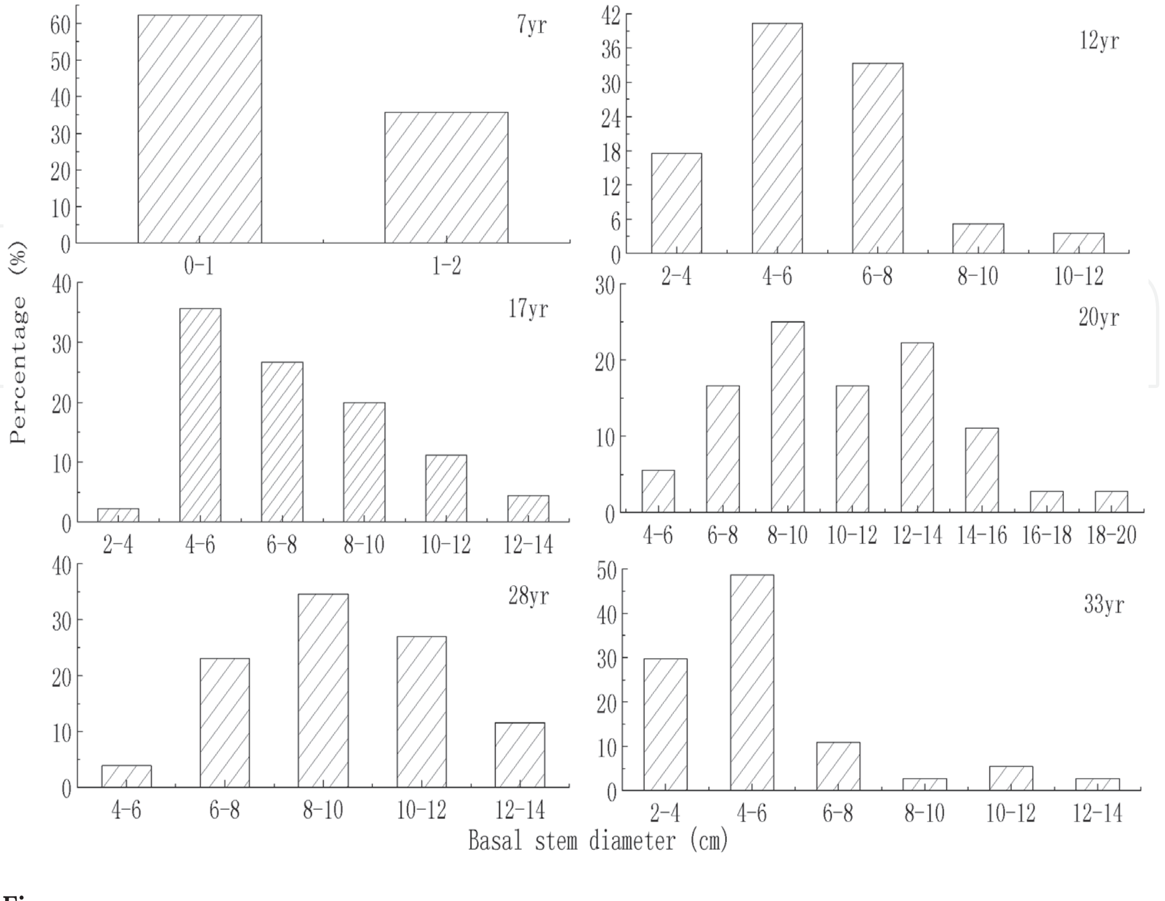

Figure 3.
Dynamitic distribution of H. ammodendron *basal stem diameter (BSD) in canopy layer at different chronosequence stage.*

seedling was HT ≤30 cm, grade II seedling was 31 ≤ HT <50 cm, and grade III seedling was HT ≥50 cm. respectively. The survival numbers of each grade seedlings were recorded respectively according to the following criteria. The grade I seedling status was considered 'Good', 'Medium' and 'Bad', if their number was >5000, 3000 ~ 4999 and < 2999. Grade II seedling status was considered 'Good', 'Medium' and 'Bad', if their number was >3000, 1000 ~ 2999 and < 999. Grade III seedling status was considered 'Good', 'Medium' and 'Bad', if their number was ≥5000, 500 ~ 4990 and < 500.

It can be seen from **Table 2** and 7-yr-old plantation already had the weaker ability of regeneration. In the plantation age of 7, 12, 17, 28, and 33, grade I seedlings all accounted greater proportion. Especially in 28-yr-old plantation, 67.3% of the total regenerated individuals (36,383 No.hm^{-2}) was grade I seedling, and grade III only accounted for 1.9%. Grade I seedlings were presented "bad" in 20-yr-old plantation. Grade II seedlings were "good" in the plantations with the age of 17 to 28. Grade III seedlings were "good" only in 17 and 33 yrs. old plantation. In contrast, there were not only abundant grade I seedlings but also larger proportion of grade III individuals (29.3%) in 17-yr-old plantation. For 33-yr-old plantation, although seedling density was only 9,433 No.hm^{-2}, the ratio of grade III reached 40.3%. The growth quality of grade III seedling was better than others apparently in 12-yr-old and 17-yr-old plantations. Especially in the 17-yr-old one, the average height and basal stem diameter of grade III seedling even reached 1.2 m and 1.9 cm, respectively (**Table 2**).

The quantity and growth quality of older seedlings is more important for the sustainable development of population [7]. As shown in **Figure 4**, the best growth status of grade III seedlings was in 17-yr-old plantation, average height and basal stem diameter reached 1.10 m and 1.91 cm respectively, and the maximum were 2.19 m and 3.89 cm, respectively. Height of grade III seedlings was more evenly in 28-yr-old plantation, which was mainly distributed between 0.51 ~ 1.02 m. For 33-yr-old plantation, the density and growth of the grade III seedlings were similar with the 28 yrs. old one.

2.3.2 Analysis on influencing factors of natural regeneration in H. ammodendron *plantation*

Results of the relational degree (Rd) between natural regeneration and its influencing factors shown in **Table 3**. Among six vegetation factors, above-ground biomass of the *H. ammodendron* individuals in canopy storey was closely related with density of seedlings in the regeneration storey (Rd = 0.77). But the density of grade III seedlings was mainly influenced by the density (Rd = 0.71) and age (Rd = 0.70) of the individuals in the canopy storey. Furthermore, density of seedlings had greatest Rd. with SHN (Rd = 0.87), as followed by SEP (Rd = 0.84) and SWC (Rd = 0.79). While the density, height and basal stem diameter of grade III

Grade	Chronosequence stage (yr)											
	7		12		17		20		28		33	
	Density	Rank	Density	Rank	Density	Rank	Density	Rank	Density	Rank	Density	Rank
I	100	B	4300	G	8733	G	783	M	24483	G	4117	G
II	683	B	1983	M	7200	G	3150	G	11200	G	1517	M
III	33	B	583	B	6600	G	1000	B	700	B	3800	M

Grade I: HT < 30 cm, Grade II: 31 ≤ HT < 50 cm, Grade III: HT ≥ 50 cm. The unite of density is No.hm^{-2}. 'G, M and B' in the table stand for 'good, medium and bad' respectively.

Table 2.
Quality and quantity of seedlings with three grades in H. ammodendron *plantation at different chronosequence stage.*

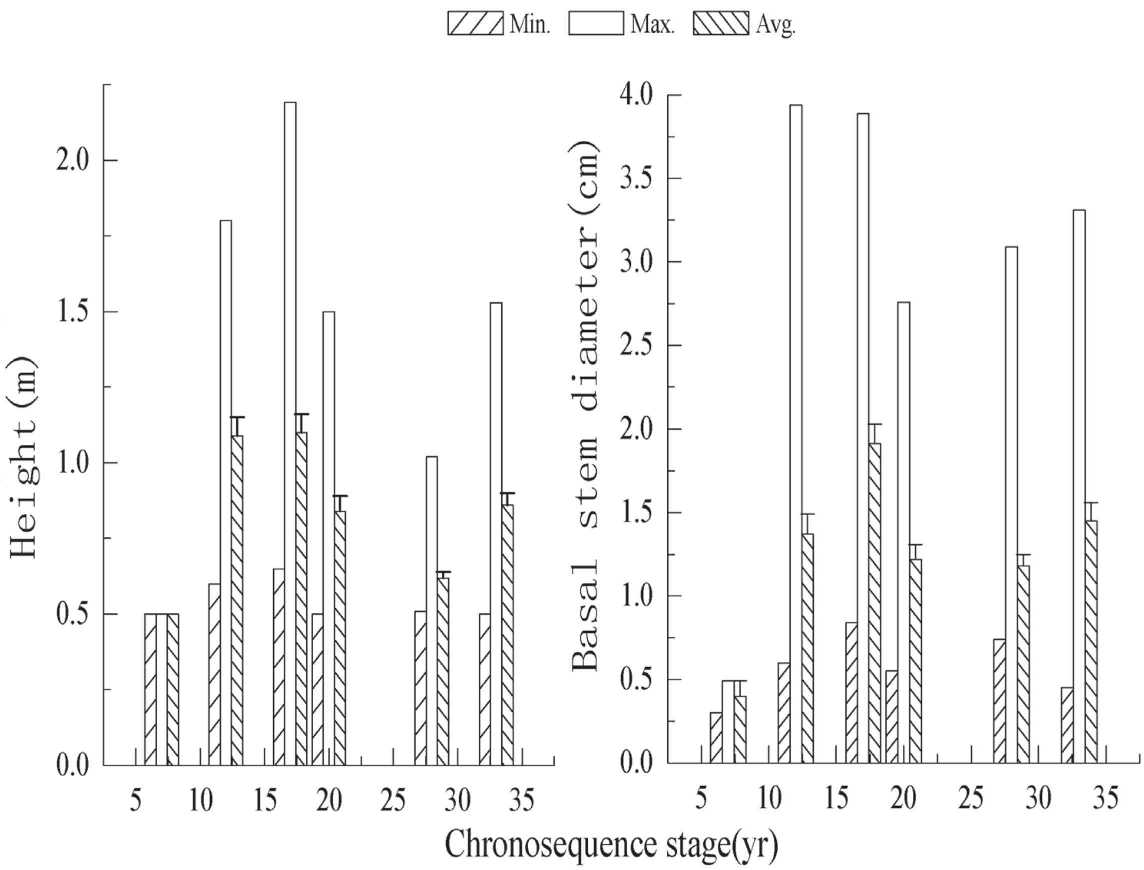

Figure 4.
Height and Basal Stem Diameter of grade III seedling (HT ≥ 50 cm) in H. ammodendron *plantation at chronosequence stage.*

Rd	X1j	X2j	X3j	X4j	X5j	X6j	X7j	X8j	X9j	X10j	X11j	X12j	X13j
X1i	0.68	0.72	0.62	0.68	0.72	0.77	0.79	0.75	0.76	0.66	0.87	0.84	0.73
X2i	0.70	0.71	0.62	0.64	0.65	0.68	0.73	0.65	0.63	0.78	0.77	0.72	0.64
X3i	0.69	0.70	0.75	0.70	0.69	0.63	0.82	0.74	0.81	0.87	0.72	0.67	0.72
X4i	0.74	0.67	0.71	0.78	0.71	0.66	0.76	0.65	0.76	0.94	0.71	0.70	0.77

X1i: density of seedling (No·hm^{-2}), X2i: density of grade III seedling (No·hm^{-2}), X3i: height of grade III seedling (m), X4i: basal stem diameter of grade III seedling (cm), X1j: plantation age (yr), X2j: planting density (No·hm^{-2}), X3j: density of canopy storey (%), X4j: height of regeneration storey (m), X5j: crown projected area of canopy storey (m2·tree^{-1}), X6j: Above-ground biomass of canopy storey (kg·tree^{-1}), X7j: SWC(%), X8j: pH, X9j: EC (ms·cm^{-1}), X10j: SOM (g·kg^{-1}), X11j: SHN (mg·kg^{-1}), X12j: SEP (mg·kg^{-1}), X13j: SAP (mg·kg^{-1}).

Table 3.
The relational degree (Rd) between characteristic of seedling and its related influencing factors.

seedlings were strongly influenced by SOM, Rd. was 0.78, 0.87 and 0.94 respectively, which explained that influence of SOM become more important than SHN for grade III seedlings. The soil pH of 8.1 to 8.6 had less influence on natural regeneration. In Minqin Desert, when soil pH was equal to or higher than 8.6, natural regeneration of *H. ammodendron* would be limited [28]. On the whole, soil environmental factors generally had greater influence on natural regeneration than that of vegetation factors of the canopy storey.

2.4 Population development characteristics of *H. ammodendron* plantation

Static Life Table was made according to relevant parameters calculated by actual measurment data of survival individual (a_x) in canopy storey and regeneration storey, the mutual relationship of parameters were as follow: $l_x = a_x/a_0 \times 1000$, $d_x = l_x\text{-}l_{x+1}$, $q_x = d_x/l_x \times 100\%$, $L_x = (l_x + l_{x+1})/2$, $T_x=\sum_x^{\infty} Lx$, $e_x = T_x/l_x$. Where a_x is the existing number of age x, l_x was standardized number, d_x was number of death interval, q_x was average survival rate per age stage, L_x was life between the interval, T_x was total life, e_x was mean expectation of life. When *H. ammodendron* individuals in canopy storey grew up to the age of 17, q_x rose obviously at age class above V, and the highest q_x appeared at age class below IV. In 7-yr-old plantation, the largest e_x was at age class I. And in the plantation with the age of 12, 17, 20, 28 and 33, the largest e_x presented at age class IV, II, VI, III and IV, respectively. It inferred that survival ability of *H. ammodendron* could be declined gradually with its growth (**Table 4**).

Variation tendency of survival and death curves were similar in the same plantation, and discrepancy still existed among six *H. ammodendron* plantations. The survival curve of 7-yr-old plantation was a skewed normal curve, and the survival rate and death rate were higher for I-age-class seedlings than others, and they were the highest for II-age-class seedlings. The survival curve of the 12-yr-old plantation showed Deevey-III type, that is, the early death rate was higher, the selection intensity of the environmental seize was greater, less than 10% of the seedlings could pass through this seize and enter the II-age-class. The transition from the seedling stage to the vegetative development stage was relatively balanced. Along with the increase of age, the environmental seize intensity at the vegetative development stage weakened, and the survival and death amount tended to level off (**Figure 5**).

2.5 Comprehensive evaluation of vegetation and soil system of *H. ammodendron* plantation

2.5.1 The change characteristics of the vegetation and soil of H. ammodendron *plantation*

The growth of *H. ammodendron* was rapid during 7 to 12 years after planting, and it began to decline after age 20, when the height, basal stem diameter, and crown width reached the maximum. During the age of 7 to 42, the tissue water content (TWC) and Proline mass fraction in the assimilated branches of *H. ammodendron* showed three curvilinear changes trend, i.e., increased from age 7 to 15, and then decrease slowly from age 30 to 35, after that increased again. Along with the increase of *H. ammodendron* age, the cell damage rate of *H. ammodendron* decreased inversely, the nitrogen mass fraction increased linearly and chlorophyll mass fraction increased exponentially. The critical change point of phosphorus mass fraction occurred at about the age of 25, showing a typical parabolic change characteristic. Meanwhile, the change trend of potassium mass fraction was irregular. For seven soil factors, only SHN (Y) had a power function regression relationship with plantation age (X) ($Y = 0.219X^{1.289}$, $F = 10.997$, $R^2 = 0.611$, $P = 0.013$), while SEP and SAP had no linear regression relationship with the plantation age. The EC increased along with plantation age, which might be caused by the accumulation and deposition of soluble salts in litters (**Table 5**).

2.5.2 Classification system and evaluation criteria of vegetation and soil coupling type of H. ammodendron *plantation*

According to the coupling coordination degree (D), combined with the comprehensive evaluation function of vegetation f(x) and soil environment g(y) calculated based on the classification method of Peng [29], the vegetation-soil coupling

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Tree height class	7 yr			12 yr			17 yr			20 yr			28 yr			33 yr		
	a_x	q_x	e_x	a_x	q_x	e_x	a_x	q_x	e_x	a_x	q_x	e_x	a_x	q_x	e_x	a_x	q_x	e_x
I (0–0.5 m)	61	−180.3	2	375	960	0.7	943	814.4	1	236	830.5	0.9	2142	981.3	0.5	338	468.5	1.3
II (0.5-1 m)	72	777.8	0.8	15	133.3	5.6	175	57.1	2	40	625	1.9	40	975	1.2	180	758.1	1
III (1–1.5 m)	16	937.5	0.6	13	230.8	5.4	165	739.4	1.1	15	666.7	3.2	1	1000	26.5	43	702.9	1.5
IV (1.5-2 m)	1	0	1.5	10	−800	5.9	43	534.9	1.6	5	1000	7.7	0	0	0	13	−471.8	2.7
V (2–2.5 m)	1	0	0.5	18	166.7	2.5	20	200	1.9	0	0	0	0	0	0	19	789.5	1
VI (2.5-3 m)	/	/	/	15	200	1.9	16	562.5	1.3	1	−2000	35.5	1	−7000	25.5	4	250	2
VII (3–3.5 m)	/	/	/	12	250	1.3	7	428.6	1.2	3	−333.3	11.2	8	−250	2.6	3	0	1.5
VIII (3.5-4 m)	/	/	/	9	0	0.5	4	750	0.8	4	−3000	7.5	10	400	1.2	3	0	0.3
IX (4–4.5 m)	/		/	/	/	/	1	0	0.5	16	625	1.3	6	833.3	0.7	/	/	/
X (4.5-5 m)	/		/	/	/	/	/	/	/	6	500	1.5	1	0	0.5	/	/	/
XI (5–5.5 m)	/		/	/	/	/	/	/	/	3	0	1.5	/	/	/	/	/	/
XII (5.5-6 m)	/		/	/	/	/	/	/	/	3	0	0.5	/	/	/	/	/	/

Table 4.
Life table of six H. ammodendron *plantations at different chronosequence stage.*

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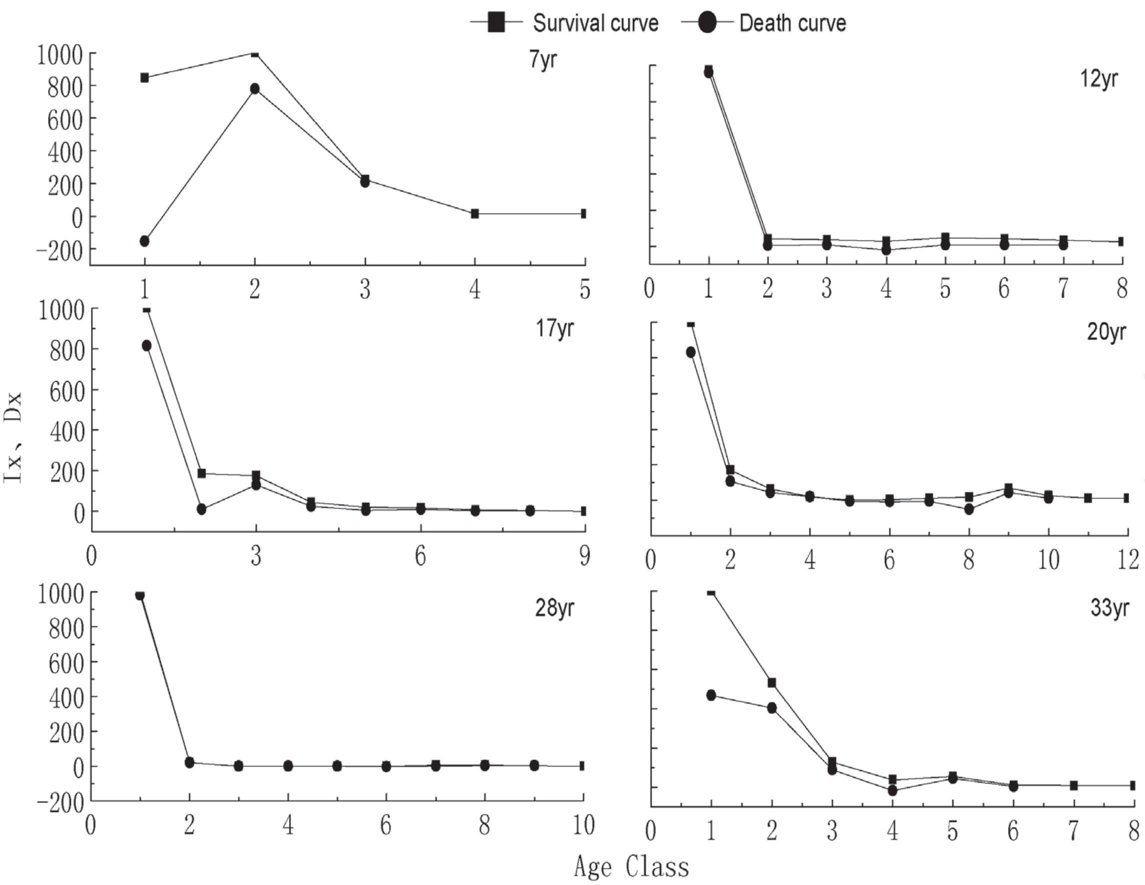

Figure 5.
Standard survival and death curves of H. ammodendron *plantations at different chronosequence stage.*

coordination type and evaluation criteria of *H. ammodendron* plantation were proposed, result shown in **Table 6**. If the ratio of f(x) to g(y) was bigger than 1, it indicated that the growth and development speed of vegetation was faster than that of soil. If the ratio was smaller than 1, it indicated that the growth and development speed of vegetation was slower than that of soil, and soil fertility resources were not fully utilized by the vegetation. If the ratio was closer to 1, it indicated that the succession state between them was more synchronous and coordinated. According to the D and the ratio between f(x) and g(y), the vegetation and soil coordinated development could be divided into 5 categories and 15 sub-categories. The coupling intensity and coupling coordination were not in one-to-one correspondence relationship, and both of them often appeared alternately, which was in line with the fluctuating development law between vegetation and soil subsystems.

2.5.3 Coupling coordination analysis of vegetation and soil system of H. ammodendron *plantation*

According to the data of **Table 7**, vegetation-soil coupling degree (C) of plantation was arranged on the order of 33 > 23 > 42 > 20 > 17 > 28 > 12 > 15 > 7. When *H. ammodendron* grew up to the age of 17, the interaction between vegetation and soil increased obviously and tended to be stable. The C of the 33-yr-old plantation was 73.85% increased than 7-yr-old one. The D of *H. ammodendron* plantations was arranged on the following order: 28 > 42 > 20 > 17 > 33 > 12 > 23 > 15 > 7. The D of 28-yr-old plantation was 96.63% increased than 7-yr-old one.

On the whole, the C and D of nine plantations showed a fluctuating and increasing trend along with the age increasing. *H. ammodendron* populations always kept at the level of disorder and declining, and vegetation and soil were in the state

Chronosequence stage(yr)	Vegetation comprehensive index f(x)											Soil comprehensive index g(y)						
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X10	Y1	Y2	Y3	Y4	Y5	Y6	Y7
7	0.60	0.89	0.12	0.05	43.3	0.28	49.41	0.53	1.25	0.17	2.14	0.93	0.84	2.97	1.80	58.93	8.38	0.09
12	2.81	5.69	4.37	3.82	63.71	0.26	52.56	0.58	1.59	0.09	1.26	6.15	3.06	4.02	2.04	173.5	9.31	1.62
15	2.84	6.08	5.93	4.88	65.66	0.25	40.04	0.94	1.22	0.11	1.5	5.49	0.91	6.72	1.86	64.4	8.03	0.16
17	2.64	7.22	3.05	5.57	61.61	0.36	43.86	0.61	1.43	0.087	2.69	5.14	4.08	15.9	3.68	163.6	7.93	0.76
20	4.29	10.67	11.09	16.17	64.3	0.23	36.60	0.82	1.79	0.11	2.75	1.52	2.74	10.79	3.99	254.8	8.86	0.89
23	2.15	5.59	3.50	3.57	61.67	0.27	27.55	1.06	1.34	0.09	1.27	3.05	1.22	6.88	1.83	84.3	9.67	0.6
28	3.68	9.59	9.24	11.00	62.12	0.23	36.60	0.82	1.79	0.11	2.74	4.33	2.91	31.52	6.85	275.5	8.49	2.09
33	2.37	5.48	3.04	3.59	60.73	0.23	36.60	0.82	1.79	0.11	2.74	3.36	3.94	7.46	3.14	152.6	7.88	0.33
42	2.55	8.70	6.41	8.52	68.75	0.50	33.23	1.06	1.83	0.18	1.92	1.48	1.46	45.32	2.74	124	8.84	1.24

X1: Height (m), X2: Basal stem diameter (cm), X3: Crown projected area of canopy storey ($m^2 \cdot tree^{-1}$), X4: Above-ground biomass of canopy storey ($kg \cdot tree^{-1}$), X5: Tissue water content (%), X6: Proline mass fraction ($ug \cdot g^{-1}$), X7: Cell damage rate(%), X8: Chlorophyll mass fraction ($mg \cdot g^{-1}$), X9: Nitrogen mass fraction(%), X10: Phosphorus mass fraction(%), X11: Potassium mass fraction(%). Y1: SWC(%), Y2: SOM ($g \cdot kg^{-1}$), Y3: SHN ($mg \cdot kg^{-1}$), Y4: SEP ($mg \cdot kg^{-1}$), Y5: SAP ($mg \cdot kg^{-1}$), Y6: pH value, Y7: EC ($ms \cdot cm^{-1}$).

Table 5.
The basal characteristic of vegetation and soil in H. ammodendron *plantations.*

Coupling coordination degree (D)	Type level	f(x)/g(y)	Coupling coordination type
0<D ≤ 0.1	Extreme imbalance of recession	>1.2	Highly disordered and declining class vegetation profit and loss type
		0.8 ~ 1.2	Highly disordered and declining class vegetation-soil co-loss type
		<0.8	Highly disordered and declining class soil profit and loss type
0.1<D ≤ 0.2	Serious imbalance of recession	>1.2	Seriously disordered and declining class vegetation profit and loss type
		0.8 ~ 1.2	Seriously disordered and declining class vegetation-soil co-loss type
		<0.8	Seriously disordered and declining class soil profit and loss type
0.2<D ≤ 0.3	Moderate imbalance of recession	>1.2	Moderately disordered and declining class vegetation profit and loss type
		0.8 ~ 1.2	Moderately disordered and declining class vegetation-soil co-loss type
		<0.8	Seriously disordered and declining class soil profit and loss type
0.3<D ≤ 0.4	Mild imbalance of recession	>1.2	Slightly disordered and declining class vegetation profit and loss type
		0.8 ~ 1.2	Slightly disordered and declining class vegetation-soil co-loss type
		<0.8	Slightly disordered and declining class soil profit and loss type
0.4<D ≤ 0.5	Brink imbalance of recession	>1.2	Nearly disordered and declining class vegetation profit and loss type
		0.8 ~ 1.2	Nearly disordered and declining class vegetation-soil co-loss type
		<0.8	Nearly disordered and declining class soil profit and loss type

Table 6.
Types of vegetation and soil coupling coordinated development.

of profit and loss. However, the degree of disorder on profit and loss showed the trend from serious to slight. (**Table 7**).

2.5.4 Comprehensive evaluation of vegetation and soil system of H. ammodendron *plantation*

Through principal component analysis, the overall information of the original 18 variables were replaced by the first 5 principal components, contribution rate was 90.91% (**Table 8**). Among them, the Eigen Value of the first principal component was 7.531, which accounted for 41.84% of the total variation and formed a correlation with above-ground biomass (0.900), crown projected area (0.874), basal stem diameter (0.831), and tree height (0.830) etc.. Therefore this principal component could represent the growth characteristic index of vegetation. The Eigen Value of the second principal component was 3.486, which accounted for 19.37% of the total variables. The chlorophyll mass fraction (0.918) had a greater positive effect on it, and the cell damage rate (−0.858) had a strong negative correlation, so this

Chronosequence stage (yr)	f(x)	g(y)	C	D	f(x)/g(y)	Coupling coordination type
7	0.083	0.043	0.575	0.190	1.958	Seriously disordered and declining class vegetation profit and loss type
12	0.098	0.146	0.817	0.316	0.668	Slightly disordered and declining class soil profit and loss type
15	0.104	0.064	0.749	0.251	1.620	Moderately disordered and declining class vegetation profit and loss type
17	0.108	0.141	0.917	0.338	0.768	Slightly disordered and declining class soil profit and loss type
20	0.146	0.113	0.919	0.345	1.297	Slightly disordered and declining class vegetation profit and loss type
23	0.091	0.080	0.978	0.289	1.143	Moderately disordered and declining class vegetation-soil co-loss type
28	0.134	0.187	0.871	0.374	0.717	Slightly disordered and declining class soil profit and loss type
33	0.106	0.109	0.999	0.328	0.973	Slightly disordered and declining class vegetation - soil co-loss type
42	0.137	0.118	0.972	0.351	1.164	Slightly disordered and declining class vegetation - soil co-loss type

Table 7.
The comprehensive evaluation on coupling coordination of vegetation and soil system of H. ammodendron *plantations at different chronosequence stage.*

principal component mainly could reflect the physiological characteristics of the vegetation. The SMC (0.947) had the greatest positive effect on the third principal component, so the principal component could mainly reflect the physical characteristics of soil. The variable related to the fourth principal component was sHN (0.808), so this principal component could represented the nutrient characteristics of soil. The variable which had the greatest negative effect on the fifth principal component was potassium mass fraction of vegetation (−0.805), so this principal component could represent the nutrient characteristics of vegetation. The extracted five principal components could represent the variables including the growth, physiological and nutrient characteristics of vegetation, physical and chemical characteristics of soil. So these five principal components could be used to replace the comprehensive evaluation score of the identification and evaluation index system of *H. ammodendron* plantation.

Through the comprehensive evaluation scores of *H. ammodendron* plantation in **Table 9**, it could be seen that the 42-yr-old one ranked the first, followed by plantation with the age order of 28, 20, 23, 12, 15, 17, 33 and 7. That is to say, during the process of sand fixation, the comprehensive score calculated based on the five principal component scores increased gradually, thus the comprehensive ranking was gradually higher than before. (**Table 9**).

2.6 Conclusions and discussion

The constructive species could regenerate successfully, which is the basic premise of sustainable development of artificial forest. The 7-yr-old *H. ammodendron* plantation, in the southern fringe of Gurbantunggut Desert, had weak self-generation ability and it could maintain such ability until the age of 33. During the process of individuals growth in canopy storey, there were abundant regenerated individuals of the grade I seedlings under canopy, which indicated that the *H.*

Factor	Component				
	1	2	3	4	5
Tissue water content (%)	0.389	0.651	0.49	0.275	−0.169
Proline mass fraction (ug·g^{-1})	−0.155	0.167	−0.111	0.907	−0.027
Cell damage rate (%)	−0.184	−0.858	0.162	−0.067	−0.005
Chlorophyll mass fraction (mg·g^{-1})	0.074	0.918	−0.142	0.188	−0.201
Nitrogen mass fraction (%)	0.766	0.093	0.044	0.345	0.156
Phosphorus mass fraction (%)	−0.089	−0.147	−0.821	0.495	0.068
Potassium mass fraction (%)	0.533	−0.128	−0.143	−0.019	−0.805
Height(m)	0.830	0.356	0.319	−0.152	−0.022
Basal stem diameter (cm)	0.831	0.457	0.198	0.155	0.017
Crown projected area (m^2·tree^{-1})	0.874	0.378	−0.034	−0.082	−0.127
Above-ground biomass (kg·tree^{-1})	0.900	0.325	−0.094	−0.03	0.02
SWC(%)	0.071	−0.238	0.947	−0.02	−0.076
SHN (mg·kg^{-1})	0.469	0.247	−0.14	0.808	0.036
SEP (mg·kg^{-1})	0.83	−0.64	0.084	0.056	0.331
SAP (mg·kg^{-1})	0.949	−0.123	0.231	−0.068	0.129
SOM(g·kg^{-1})	0.402	−0.216	0.647	0.001	0.515
EC (ms·cm^{-1})	0.742	−0.203	0.325	0.352	−0.348
pH value	0.121	0.087	−0.007	−0.17	−0.898
Eeigen value	7.531	3.486	2.469	1.619	1.259
Relative variance contribution (%)	41.840	19.369	13.715	8.996	6.994
Accumulated Variance Contribution Rate (%)	41.840	61.208	74.923	83.918	90.912

Table 8.
The Eigen values and contribution rate of the principal constituent.

Chronosequence stage (yr)	F1	F2	F3	F4	F5	Comprehensive Evaluation score	Ranking
7	−1.869	−0.133	1.422	−0.135	1.209	0.210	9
12	−0.160	−1.092	−1.365	1.401	0.935	0.723	5
15	−0.563	0.430	−0.724	−0.883	−0.701	0.601	6
17	0.051	−1.046	0.324	0.679	−1.415	0.471	7
20	1.239	0.009	0.181	−1.465	0.923	0.815	3
23	−0.549	0.924	−1.561	−0.541	−0.009	0.739	4
28	1.440	−0.474	0.449	0.148	0.662	0.897	2
33	−0.085	−0.627	0.589	−0.602	−1.345	0.425	8
42	0.496	2.010	0.683	1.398	−0.261	0.918	1

Table 9.
Comprehensive evaluation of H. ammodendron *plantations.*

ammodendron seeds can successfully germinated and grew into seedlings, as well as reflected the characteristics of high maturing rate, short seed dormancy period and high germination rate of the *H. ammodendron.* Which was also the main reason for abundance of grade I seedling (HT < 30 cm). The number of grade I seedlings accounted for the largest proportion in regeneration storey, and rich seedling bank could provide a strong guarantee for the regeneration and succession of the population [30]. However, the large seedling bank could not guarantee proper regeneration and ensure sufficient number of higher grade seedlings, and grade III seedlings (HT ≥ 50 cm) were the key for transferring from the regeneration storey to the canopy storey, and thus realizing natural regeneration and sustainable development of the *H. ammodendron* population. Therefore, moderate thinning and tending measures should be taken for *H. ammodendron* plantation to form a more stable structure. The SHN was the main influencing factor of seedling regeneration in *H. ammodendron* plantation. Therefore, avoiding destroy the shrub and grass with strong nitrogen fixation ability, and properly retaining withered litters on soil surface would increase the SHN content in soil, and at last would promote the growth of seedlings.

The *H. ammodendron* plantation system, at the south edge of Gurbantunggut Desert, had weak self-optimization ability, the interdependence and mutual restriction relationship between vegetation and soil. Along with the increase of the plantation age, the ratio of f(x)/g(y) gradually increased too. It showed that *H. ammodendron* population restoration measures had a strong ability to adapt to the environment, and the growth and development speed of population exceeded the development speed of soil, and this may indicate that such vegetation was able to adapt to the local environment, but had a limited ability to reconstruct the soil. When the plantation developed to the age of 42, the coupling degree (C) and coupling coordination degree (D) between vegetation and soil system, f(x)/g(y) were relatively larger, it could be inferred that the vegetation-soil system of the *H. ammodendron* plantation tended to transform from a declining type to a coordinated development type. It is concluded that the competition of vegetation growth would be more intense in the coming years. Therefore, artificial management measures, such as spring water collection, regular fertilization and tree pruning are needed to promote the healthy growth of *H. ammodendron* and the natural regeneration of seedlings, so as to improve the diversity and coverage of vegetation, in order to enhance the coordination degree of vegetation and soil, and finally realize the transformation to a high-level coupling state.

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References

[1] Johnson, J.B. 1997. Stand structure and vegetation dynamics of a subalpine wooded fen in Rocky Mountain National Park, Colorado. J. Veg. Sci., 8 (3): 337-342.

[2] Agren, J., and Zackarisson, O., 1990. Age and size structure of *Pinus sylvestris* populations on mires in Central and Northern Sweden. J. Ecol., 78: 1049-1062.

[3] Song, C.W., Liu C.J., Halik Ü., et al. 2021. Spatial Distribution and Structural Characteristics for Haloxylon ammodendron Plantation on the Southwestern Edge of the Gurbantünggüt Desert. Forests, 12(5), 633-633.

[4] Liu, G.J., Zhang, X.M., Li, J.G., Wu, J.X., Wei, J., Li, J.L., Wang, X.W. 2010. Analysis on dynamic life table of natural Haloxylon ammodendron at seedling stage in the southeastern marginal zone of the Junggar Basin. Arid Zone Res., 27 (1): 83-87.

[5] Qian, Y.B., and Li, Y.F. 1999. Study on soil physical properties of desertified land in Mosuowan Reclamation Area. Arid Zone Res., 26(2): 31-37.

[6] Zhou, C.B., Song, Y.Y. 2015. Influence of different longitudinal dune positions in the Gurbantunggut Desert on the reproduction of Haloxylon ammodendron seedlings. Appl. Ecol. Env. Res., 13(1): 99-113.

[7] Magnus-Lof, D.C., Dey-Rafael, M.N., Douglass, F.J. 2012. Mechanical site preparation for forest restoration. New. For., 43: 825-848.

[8] Vacek, S.I., Nosková, L., Bílek, Z., Vacek, O.S. 2010. Regeneration of forest stands on permanent research plots in the Krkonoše Mts. J. For. Sci., 56(11): 541–554.

[9] Zhang, X.Y., Wang, X.M., Yan, P. 2007. Re-evaluating the impacts of human activity and environmental change on desertification in the Minqin Oasis, China. Env. Geo., 55(4): 705-715.

[10] Wang G.H., Zhao W.Z. 2015. Effects of seed density on the germination and seedling growth of Haloxylon ammodendron. Journal of Desert Research, 35(5): 1248-1253.

[11] Vander K.J., Yassir I., Buurman P. 2009. Soil carbon changes upon secondary succession in Imperata grasslands (East Kalimantan, Indonesia) [J]. Geoderma. 149(1-2): 76-83.

[12] SU Y.Z., and LIU T.N. 2020. Soil Evolution Processes Following Establishment of Artificial Sandy-fixing Haloxylon Ammodendron Forest. Acta Pedologica Sinica, 57(1): 84-91.

[13] Karlen D.L., Rosek M.J., Gardner J. C., et al. 1999. Conservation reserve program effects on soil quality indicators[J]. Journal of Soil and Water Conservation, 54: 439-444.

[14] Research group of "study on combating desertification/degradation in china. 1998. Study on combating desertification/degradation in China. Beijing: Environmental Science Press.

[15] Zhou, Z.B., Xu, X.W. 2002. Absorption characteristics of ions in three species of shrubs of the artificially-planted greenbelts in the Hinterland of Taklamakan Desert. Arid Zone Res., 19 (1): 49-52.

[16] Han, W., Xu, X.W., Li, L., Lei, J.Q., Li, S.Y. 2010. Chlorophyll a fluorescence responses of *Haloxylon ammodendron* seedlings subjected to progressive saline stress in the Tarim Desert highway ecological shelterbelt. Photosynthetica, 48(4): 635-640.

[17] Arabzadeh, N. 2011. A Study on the impact of drought stress on changes of free proline in two species of Haloxylon persicum and Haloxylon aphyllum. J. Plant Sci., 6(5): 190-201.

[18] Li, Y.F. 1992. Effects of different moisture habitats on water consumption of Haloxylon ammodendron. Arid Zone Res., 9(4): 45-50.

[19] Wang, X.Q., Wang, T., Jiang, J., Zhao, C.J. 2005. On the sand surface stability in the southern part of Gurbantunggut Desert. Science in China Series D: Earth Sciences, 48(6): 778-785.

[20] Huang, P.Z., Liu, Z.J., Cui, W.C. 1985. A preliminary study on water harvesting afforestation of Haloxylon ammodendron. Xinjiang Agricultural Sciences, 23-25.

[21] Qian, Y.B., and Li, Y.F. 1999. Study on soil physical properties of desertified land in Mosuowan Reclamation Area. Arid Zone Res., 26(2): 31-37.

[22] Phillips, D.L., and MacMahon, J.A. 1981. Competition and spacing patterns in desert shrubs. J. Ecol., 69: 97-115.

[23] Song, Y.Y., and Hu, X.J. 2011. Estimation models of the aboveground biomass of *Haloxylon ammodendron* in the different ecotype of the Gurbantunggut Desert. J. Northwest For. Univer., 26(2): 31-37.

[24] Rundel, P. 1971. Community structure and stability in the giant sequoia groves of the Sierra Nevada. Am. Midl. Nat., 85:478-492.

[25] Liu, G.J., Zhang, X.M., Li, J.G., Wu, J.X., Wei, J., Li, J.L., and Wang, X.W. 2010. Analysis on dynamic life table of natural *Haloxylon ammodendron* at seedling stage in the southeastern marginal zone of the Junggar Basin. Arid Zone Res., 27(1): 83-87.

[26] Blackman, G.E. 1942. Statistical and ecological studies in the distribution of species in plant communities: I. Dispersion as a Factor in the Study of Changes in Plant Populations. Ann. Bot., 6: 351-370.

[27] China's State Forestry Administration (SFA). 2010. Forest resources planning survey, GB/T 26424 State Forestry.

[28] Li, F.J., Sun, D.X., Chang, Z.F. 2008. Preliminary study on natural regeneration mechanism of *H. ammodendron* forest in Minqin desert area. Chinese Agricultural Science Bulletin, 24(9): 165-170.

[29] Peng, W.X., Song T.Q., Zeng, F.P. et al. 2011. Model of vegetation and soil coupling coordinative degree in grain for green project in depression between karst hills. Transactions of the CSAE, 27 (9): 305-310.

[30] Li G.L., Zhang D.H., Zhang Z.S., et al. 2020. Population dynamics of main sand-fixing shrubs in the Gurbantunggut Desert. J. of Desert Research, 41(2):129-137.